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FORMULATION OF CONSUMABLES MANAGEMENT MODELS

28 JANUARY 1977 CONTRACT NO. NAS9-14264

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MISSION PLANNING PROCESSOR

PAYLOAD INTERFACE DEFINITION

Prepared by

J. G. Torian

Systems Analysis Section

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DEFENSE AND SPACE SYSTEMS GROUP

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TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIST OF TABLES

1.0 INTRODUCTION

Formulation of consumables models required for the mission planning and scheduling function and establishment of the relation of those models to prelaunch, onboard, ground support, and postmission functions for the Space Transportation Systems (STS) is being conducted under this Contract. The development includes analytical models consisting of an Orbiter Mission Planning Processor (Reference 1) with appropriate consumables data base, a method of recognizing potential constraint violations in both the planning and flight operations functions, and a Flight Data File storage/retrieval of information over an extended period which interfaces with a Flight Operations Processor for monitoring of the actual flights.

This report presents the definition of the payload interface to the Mission Planning Processor and is structured to achieve the following goals:

1. Define the impact of payload functions on Orbiter operations.

2. Provide a guide to assessing this impact via reference to a typical payload data source and the related input to the Mission Planning Processor.

3. Identify modifications to the Mission Planning Processor which will improve the interface of the payload data source and the Processor.

4. Identify the data and format for payload data sources which would improve the interface of that source and the Mission Planning Processor.

2.0 PAYLOAD DATA SOURCES

Typical payload data sources which support the mission planning process are given for automated and sortie payloads in Reference 2 and 3, respectively. Data for selected missions are included in Appendix A and B to acquaint the reader with the format and reference data entry provision as described in the text. Appendix A and B include only those data sheets referenced in the text. These data are referenced as typical since there is currently not an established authoritative payload data source in effect. The subsequent text references these data as "automated payload data" and "sortie payload data".

3.0 PAYLOAD INTERFACE

The definition of standard flight/mission components, representing portions of a flight which are to be combined in various sequences to satisfy a particular mission, is of practical necessity in simplification of a consumables management scheme. A particular set of Flight/Mission components has been selected for consumables management and incorporated in the Mission Planning Processor. The set is structured to consumables analysis, but is adaptable to change as other aspects of mission planning and flight operations converge on a unique and standardized set for the Shuttle.

The set of Flight/Mission components is shown on Table I. The set consists of five flight phases from prelaunch through entry and landing. The flight phases must be performed sequentially in the flight profile. The phases are further divided into phase components. The phase components are either sequential or non-sequential with respect to the profile. For all flight phases other than on-orbit, the phase components are sequential. The sequential phase components must be included in the order specified for any flight independent of the particular payload mission. The timing of these phase components is, however, affected by launch site, orbital inclination, and configuration. The impact of these effects is considered negligible with respect to consumables analysis except during the latter stages of mission planning. During these latter stages accurate timing of these phase components should be made available from the appropriate data sources. The selection and sequencing of on-orbit phases and activities is unique to a particular payload mission. The subsequent text discusses the payload interface to this selection and sequencing process. Payload interface to these on-orbit phases and activities is presented in the order shown on Table I.

Table I. Flight/Mission Components

PRELAUNCH PHASE

ASCENT PHASE

- GSE-Liftoff
- Liftoff-MECO
- MECO-ETS
- ETS-OMSign

ON-ORBIT PHASES AND ACTIVITIES

- Orbital Phases
  - OMS Maneuver
  - RCS Translation Maneuver
  - Attitude Hold
  - Rendezvous
  - Station Keeping
  - Dock
  - Undock
  - PTC
  - EVA
  - IVA
  - Manipulator Ops
  - IMU Alignment
- Orbital Activities
  - Payload Bay Doors
  - Payload Consumables
  - Computer
  - TV
  - Downlink
  - Uplink
  - Fuel Cell Purge
  - Eat
  - Sleep
  - Waste Management
  - APU Checkout

DEORBIT PHASE

- Deorbit Prep-Deorbit Burn
- Burn to Interface

ENTRY AND LANDING PHASE

- Interface to Stop Roll
- Stop Roll to GSE Connect

3.1 OMS MANEUVER

3.1.1 Description

The objective of this activity is to realize a change in the orbit of the Shuttle using the thrust generated by the OMS engines. The activity is initiated by the performance of an IMU alignment, after which the GN&C, RCS, and OMS subsystems are configured by the crew to the desired thrusting program, a rotational maneuver using the RCS thrusters is then performed to place the Shuttle in the attitude required for the burn. Ignition of the OMS engines is then effected to the thrust level and for the time duration necessary to attain the desired orbital change, with RCS thrusting used during OMS firing to maintain the proper attitude. An RCS trim burn, if required, follows OMS engines shutdown, after which a second RCS rotational maneuver is performed to fix the spacecraft attitude in the new acquired orbit. Reconfiguration of the spacecraft subsystems by the crew completes the OMS maneuver. The influence variables for an OMS maneuver are start time and ΔV required by the maneuver. The stop time, as dictated by the required burn time, is calculated internally.

3.1.2 Payload Interface

The OMS maneuver is used to satisfy the orbital parameter requirements of the mission for delivery, retrieval, or service of an automated payload and/or orbital operation of a sortie payload. Determination of the time and magnitude of the burn ΔV required to obtain the orbital parameters is an operations or flight planning function. Current payload data specifies the parameters from which a burn schedule can be developed for a particular flight.

3.1.3 Data Sources

The automated payload data specifies the orbital parameters of apogee, perigee, inclination, declination of launch asymptote, and orbital position longitude in items 80 through 92 on data sheet A-1. The type of missions; delivery, retrieval, or service, are stated in items 28 through 79. The latter entries are indicative of OMS maneuver requirements preparatory to a rendezvous. Launch site is specified in item 4. Data sheet A-11 provides a mission operations summary with a timeline of events including time to obtain desired orbit.

Apogee, perigee, and orbital inclination required by sortie payloads are specified on data sheet S-1 in items 22 through 30. Launch site is also specified in item 31.

3.14 Data Requirements

In the early stages of flight planning, the above data sources in conjunction with working curves for the ΔV required to obtain various orbital parameters can be used as input to the MPP. In the latter stages a more accurate burn schedule should be made available through the appropriate data sources.

3.2 RCS TRANSLATION MANEUVERS

3.2.1 Description

The objective of this activity is to effect an orbital change of the Shuttle by the use of the RCS thrusters. A preparation period during which GN&C equipment is activated and a rotation maneuver performed to fix the spacecraft attitude precede the translation burn. The activity is terminated after the targeted thrust has been achieved. RCS translation maneuvers are typically used during rendezvous, docking, and undocking operations. The influence variables for an RCS translation maneuver are start time and ΔV required by the maneuver. The stop time, as dictated by the required burn time, is calculated internally.

3.2.2 Payload Interface

The RCS translation maneuver is used in the same manner as the OMS maneuver (3.1) for the lower ΔV range.

3.2.3 Data Sources

Same as OMS maneuver (3.1).

3.2.4 Data Requirements

Same as OMS maneuver (3.1).

3.3 ATTITUDE HOLD

3.3.1 Description

The objective of this activity is to attain and hold within a specified deadband the Shuttle Spacecraft in a given attitude for a specified time period. The activity starts with the crew performing a rotation maneuver to place the spacecraft in the desired attitude. This attitude is then maintained at the desired deadband by the RCS thrusters. The influence variables for an attitude hold are start time, stop time, spacecraft altitude, and type of hold (local vertical or inertial).

3.3.2 Payload Interface

There are several factors in the payload mission requirements which dictate the use of a spacecraft attitude hold. First there is the direct requirement for a local vertical or stellar (inertial) hold imposed by the particular experiment. Secondly, there are indirect requirements imposed by pointing associated with communications as well as those imposed during station keeping, escort, deploy, retrieval, and/or service of an automated payload.

3.3.3 Data Sources

The automated payload data specifies the direct requirement for Shuttle attitude hold in item 24 on data sheet A-1. In some cases the position is noted such as with reference to TDRS communication. Data sheet A-11 may reference attitude hold requirements as part of the mission operations such as station keeping or escort. Pointing requirements imposed on the Shuttle for checkout and deployment are given for the on-orbit phase (phase no. 3) in Column 4 as a total duration. Data sheet A-14 includes the duration and location (Orbiter, Tug, or ground control) of communications operations; reference to TDRS via the Orbiter is indicative of pointing requirements.

The sortie payload data specifies pointing requirements on data sheet S-12 and a timeline on S-15. Use of TDRS is entered as item 24 on data sheet S-20.

3.3.4 Data Requirements

Specific periods, altitude, and type of attitude hold are required by the Mission Planning Processor. The data should reflect all attitudes hold required by the payload function, communications, and station keeping.

3.4 RENDEZVOUS

3.4.1 Description

The objective of this activity is to place the Shuttle in the proximity of another spacecraft by means of a series of propulsive maneuvers. The operations caused by this particular activity correspond to the TPF maneuvers which are initiated when the crew activates the GN&C and RCS subsystems to the desired configuration in preparation of the performance of a rotation burn to fix the spacecraft attitude, after which a braking burn is performed. A second rotation maneuver performed at the completion of the braking burn completes this activity. Note that the operations to achieve orbital transfer through TPI, or docking, are not included. The OMS maneuver activity is used for the phasing, height, co-elliptic, and TPI burns. The influence variables for the rendezvous activity are start time and ΔV required for the braking burn.

3.4.2 Payload Interface

The automated and sortie payloads require a rendezvous in the retrieval servicing or prior to docking with spacecraft and/or satellites.

3.4.3 Data Sources

The automated payload data includes a retrieval or service mission objective in data items 28 through 79 of data sheet A-1. Start time of the objective which is the maximum end time for the rendezvous sequence is given on data sheet A-11. The sortie payload data specifies the number of satellite retrievals per flight in item 40 of data sheet S-1. The time of the operation is included on S-13.

3.4.4 Data Requirements

Approximate rendezvous times obtained from the above data and the default braking burn ΔV included in the Mission Planning Processor can be used in the early stages of the mission planning process. Specific times and braking burn ΔV should be available from the appropriate data sources during the latter stages.

3.5 STATION KEEPING

3.5.1 Description

The objective of this activity is to maintain a given spatial relationship between the Shuttle and another free flying spacecraft. Although not limited to, this activity usually forms part of the rendezvous or separation sequences where a waiting period is required to satisfy specific mission and/or spacecraft requirements prior to docking or after undocking. The activity is preceded by a short preparation period in which navigation and communication equipment is activated. Spacecraft pointing or attitude hold requirements to be effected with the RCS subsystem, if required, are not included herein. The influence variables for station keeping are start time and stop time.

3.5.2 Payload Interface

The mission may require station keeping as an escort following a payload delivery and/or as associated with retrieval or service.

3.5.3 Data Sources

The automated payload data specifies station keeping (escort) on data sheet A-11. Similar data for the sortie payloads is on S-13.

3.5.4 Data Requirements

Periods in which the Shuttle Spacecraft is in the station keeping mode are required. Attitude hold, if required, should also be specified as it affects the attitude hold activity.

3.6 DOCKING

3.6.1 Description

The objective of the docking activity is to establish a physical connection between the Shuttle and another spacecraft. Docking is normally performed after a rendezvous sequence and preceded by station keeping and includes the propulsive maneuvers using the RCS subsystem to achieve contact. The activity includes a rotation and a docking burn. The influence variables for Docking are stop time (contact) and the docking burn ΔV.

3.6.2 Payload Interface

Any retrieval or mating operation with a second spacecraft during a mission which requires active participation of the Orbiter equivalent to a docking burn should be entered as a docking activity regardless of whether or not the docking port is used.

3.6.3 Data Source

Active participation of the Orbiter as defined above should be noted on data sheet A-11 (phases 5 and 9) for the automated payloads and S-13 (phase 8) for the sortie payloads.

3.6.4 Data Requirements

The time of and ΔV for operations which are the equivalent to a docking burn are required. The default ΔV included in the Mission Planning Processor is applicable to earlier stages of flight planning.

3.7 UNDOCKING

3.7.1 Description

The objective of this activity is to effect the separation of the Shuttle from another spacecraft. The activity is initiated by the configuration and activation of the GN&C and RCS subsystems to perform a translation burn to achieve the physical separation. The activity is completed after a rotation burn is performed to fix the Shuttle to the desired attitude. The influence variables for undocking are start time (separation) and the separation burn ΔV.

3.7.2 Payload Interface

Same as for Docking activity (3.6) except applicable to deployment rather than retrieval.

3.8 PASSIVE THERMAL CONTROL

3.8.1 Description

The objective of this activity is directed toward the utilization of the space environment to achieve thermal control of the Shuttle. PTC is effected by rotating at a given rate the spacecraft about one of its axes to expose the entire Shuttle to the desired environment. The activity is used to stabilize the spacecraft temperature during prolonged periods of drift flight, or to thermally condition a given subsystem prior to the performance of the activity, such as the warming of fuel lines prior to the performance of propulsive maneuvers.

3.8.2 Payload Interface

PTC is a Shuttle operational requirement. Conflicting payload operations cannot be performed during scheduled periods for the PTC activity.

3.9 EVA

3.9.1 Description

The objective of the Extra Vehicular Activity (EVA) is to allow one or more crewmen to egress the pressurized cabin into free space for the performance of a given mission objective. The activity is initiated by the crew donning the Astronaut Life Support Assembly (ALSA) that provides a safe and conditioned environment. A pure oxygen prebreathing cycle from a portable supply follows to effect denitrogenization of the crew after which the egress into free space is accomplished via the airlock. At the completion of the assigned task in free space, the crew returns to the airlock, the pressure of which is increased and equalized with that of the cabin to allow the crew entry and the re-establishing of normal systems configuration. The activity is completed with the crew doffing and recharging the ALSA package. The influence variables for this activity are start time, stop time, and number of crew members involved.

3.9.2 Payload Interface

An EVA may be required for deployment, retrieval, activation, or service of a payload.

3.9.3 Data Source

Automated payload data specifies the EVA requirements by indicating location of a specific task for payload personnel on data sheet A-17. The total number of planned EVA and the average duration is noted in item 15 and 16 of the same data sheet. It is necessary to refer to the mission operations data sheet, A-11, to establish the start time of the EVA. Requirements for contingencies are also noted in item 18 of A-17. Similar type data is noted on data sheets S-16 and S-15 for the sortie payloads. The sortie payload data references number and duration of planned EVA as items 41 and 42, data sheet S-1, in addition to that given on S-16.

3.9.4 Data Requirements

Timeline and crew members for EVAs can be established from above data sources in early mission planning stages. More accurate timelines for actual flight should be made available in latter stages of planning.

3.10 INTRAVEHICULAR ACTIVITY (IVA)

3.10.1 Description

The objective and characteristics of the IVA are similar in nature to those of the EVA inasmuch as it involves the egress of one or more crewmen from the Orbiter cabin. In the IVA the transfer is to a pressurized area which is the same as that of the Orbiter cabin, and therefore is performed in the unsuited mode, i.e., without the use of the pressurized suits, and without the necessity to unpressurize the airlock.

3.10.2 Payload Interface

Crew transfer to sortie payloads with crew working modules containing CO_2 removal provisions such as the spacelab constitute an IVA. It should be noted that the present Mission Planning Processor does not include provisions for transfer to spacecraft such as a manned Tug since life support is still provided during the EVA/IVA activities as defined.

3.10.3 Data Sources

Same as EVA (3.9) except location is noted as IVA.

3.10.4 Data Requirements

Same as EVA (3.9).

3.11 MANIPULATOR OPERATIONS

3.11.1 Description

The objective of this activity is to provide the Shuttle with the capability to remotely control the deployment and retrieval/service of payloads. The activity consists in the operation of electromechanical devices that physically remove the deployable spacecraft out of the payload bay to be released into space. These operations are supported by the activation of flood lights and television monitoring equipment. The retrieval/service operation is the same as above except that the order in which the operations are performed is reversed to effect the capture of the free flying spacecraft. The influence variables for this activity are start time and stop time.

3.11.2 Payload Interface

Manipulator operations may be required for deployment and/or retrieval of subsatellites or automated payloads.

3.11.3 Data Sources

Automated payload data implies the use of the manipulator as a payload personnel task requiring this equipment on data sheet A-17. It is necessary to refer to the mission operations data sheet, A-11, to establish the start time of the operation. Similar type data is noted on data sheets S-16 and S-15 for the sortie payloads.

3.11.4 Data Requirements

The above data sources provide estimates of the maximum time of manipulator operations since the time specified reflects the assignment of payload personnel to the task, not the actual operation of the manipulator. These data may be used as conservative estimates during the early stages of mission plannning. More accurate usage timelines should be available in the latter stages possibly based on crew training exercises with a simulator.

3.12 IMU ALIGNMENT

3.12.1 Description

The objective of this activity is to align by means of star tracker measurements the Inertial Measurement Unit of the Shuttle with respect to some coordinate system. The activity, as a rule, is performed automatically by a computer, is initiated by the crew loading the desired parameters and totally executed by the computer. If the IMU alignment errors exceed the tolerance limits, a course alignment requiring a rotation maneuver using the RCS system must first be performed and then followed by the automatic procedure to complete the alignment. One such maneuver is included in this activity. The influence variables for this activity are start time and stop time. This activity should be used when an alignment is to be performed independently of the OMS maneuver and the deorbit preparation, since it is included as a part of these activities.

3.12.2 Payload Interface

IMU alignment is an Orbiter operational requirement with no direct payload interface. However, payload position accuracy requirements as noted on data sheet A-15 (items 26 through 30) and S-19 (items 19 through 21) for the automated and sortie payloads respectively, outside the range normally provided by the Orbiter may influence the frequency of the IMU alignments.

3.13 PAYLOAD BAY DOORS

3.13.1 Description

The objective of this activity is to effect the operations required to open and close the Shuttle Payload Bay Doors. Payload bay doors are opened by means of electromechanical actuators to provide access to the payload and to deploy the radiator. This operation is performed as soon as the Shuttle arrives at its desired orbit. The doors are closed immediately prior to reentry. The influence variables are start (open) and stop (close) time for the payload bay doors in the open position.

3.13.2 Payload Interface

Payload bay door operation is an Orbiter function with no direct interface to the payload.

3.14 PAYLOAD CONSUMABLES

3.14.1 Description

The objective of this activity is that of supporting the payload operations. This support consists of the electrical energy and/or other consumables supplied to the payload from the Shuttle storage and distribution systems. A timeline of electrical power and/or rate requirements for other Shuttle supplied consumables such as O_2 or N_2 are input directly into the Mission Planning Processor.

3.14.2 Payload Interface

Payload electrical power, atmospheric control of crew habitable modules (including leakage), and payload consumables to be supplied by the Orbiter are included in this activity.

3.14.3 Data Sources

Payload electrical power requirements at the Shuttle interface for automated payloads is given on data sheet A-13. Data is given for both DC and AC requirements. Average power and peak power with the respective durations and repetition rate are specified. These data can be used to construct a coarse timeline of power requirements with reference to data sheet A-11. It should be noted that the average power as stated includes the peak; the average power during non-peak periods must be calculated. There does not appear to be any direct provisions for entry of Shuttle interface consumables requirements other than electrical power in the present automated payload data system.

Sortie payload electrical power requirements at the Shuttle interface are presented on data sheet S-15 as a power profile. As for the automated payloads, there are no direct provisions for entry of Shuttle interface consumables other than electrical power in the present sortie payload data system.

3.14.4 Data Requirements

Electrical power profile and other consumables rates required at the Shuttle interface similar to that given for the sortie payload electrical system are required for input to the Mission Planning Processor.

3.15 COMPUTER

3.15.1 Description

The objective of this activity is to support the computer requirements of the Orbiter. The influence variables for this activity are start time and stop time.

3.15.2 Payload Interface

Computer support is used in data acquisition and management, checkout, and other operations of the various payloads. A Shuttle computer is in operation while on-orbit and available for payload functions. Payload requirements for such support affect the utilization schedule of the computer only. As such, this is not a direct Shuttle interface as regards the consumables Mission Planning Processor.

3.15.3 Data Sources

Automated payload data lists the duration and location of computer support including control and display on data sheet A-15. Reference to data sheet A-11 is required to establish computer utilization scheduling. Similar data is entered on data sheet S-19 for the sortie payloads.

3.16 TV

3.16.1 Description

The objective of this activity is to provide additional television coverage over that already scheduled during the performance of EVA or Manipulator Operations. The influence variables for this activity are start time and stop time.

3.16.2 Payload Interface

TV may be required as a form of data acquisition for the payload.

3.16.3 Data Sources

Automated payload data specifies the type of data acquisition required in column 6 of data sheet A-15. If the TV is requested as the form and the information is to the Orbiter (column 6) the duration specified in column 2 is applicable to this activity. Reference to data sheet A-11 may be required to establish the actual timeline. Similar data for the sortie payload data is given on data sheet S-19. The form is in column 1 and the duration and repetition rate are in columns 4 through 6.

3.16.4 Data Requirements

Timeline of TV requirements for preliminary planning are available from the above sources. More accurate timeline of the activity is required in the latter stages of flight planning.

3.17 DOWNLINK

3.17.1 Description

The objective of this activity is to support the downlink requirements of the payload. The influence variables for this activity are start time and stop time.

3.17.2 Payload Interface

This activity is applicable when the payload requires the Orbiter to communicate in the transmit mode. The transmission may be to the ground, TDRS, or to an automated payload.

3.17.3 Data Sources

Automated payload data specifies the data and communications requirements on data sheet A-14 and A-15. Any entry which requires the Orbiter to transmit, such as control commands to the unattached automated payload, are considered downlink. Sortie payload data specifies a real time downlink as a data profile on sheet S-15.

3.17.4 Data Requirements

A downlink profile such as that specified for the sortie payloads is required by the Mission Planning Processor. Attitude hold requirements associated with the communication should also be specified since they affect that activity (3.3).

3.18 UPLINK

3.18.1 Description

The objective of this activity is to support the uplink communications requirements of the payload. The influence variables for this activity are start time and stop time.

3.18.2 Payload Interface

This activity is applicable when the payload requires the Orbiter to communicate in the receive mode. The reception may be from the ground, TDRS, or from an automated payload.

3.18.3 Data Sources

Automated payload data specifies the data communications requirements on data sheet A-14 and A-15. Any entry which requires the Orbiter to receive data, such as verification of control commands in release and deployment, are considered uplink.

Sortie payload data specifies an uplink requirement in columns 17 through 19 of data sheet S-20.

3.18.4 Data Requirements

An uplink profile is required by the Mission Planning Processor. Attitude hold requirements associated with the communication should also be specified since they affect that activity (3.3).

3.19 FUEL CELL PURGE

3.19.1 Description

The objective of this activity is to provide for the purging of impurities from the reactants used in the production of electrical energy. The activity is initiated with the activation of purge line heaters used to preclude the possibility of line freeze-up due to the accumulation of moisture, after which small quantities of oxygen and hydrogen are alternately expelled using vent valves to effect the purging. The influence variables for this activity are start time and stop time.

3.19.2 Payload Interface

This is a Shuttle operations activity and does not interface with the payload.

3.20 EAT

3.20.1 Description

The objective of this activity is to provide the food preparation facilities onboard the Shuttle Spacecraft. The activity is initiated by a short preparation period in which heaters are activated to heat up and maintain hot the food and water required for meal preparation. The activity is completed when the crew finish eating. The influence variables for this activity are start time and stop time.

3.20.2 Payload Interface

An appropriate schedule of eat periods must be provided for the payload personnel.

3.20.3 Data Sources

No direct provisions for direct entry of personnel eat periods are included in either the automated or sortie payload data. Payload personnel skill requirements are given on data sheet A-17 and S-16, respectively. This information is combined with respective mission operations data on A-11 and S-13 to arrive at an appropriate eating schedule.

3.20.4 Data Requirements

An eat period schedule for the payload personnel is required.

3.21 SLEEP

3.21.1 Description

The objective of this activity is to provide for the sleeping facilities for the crew onboard the Shuttle. The activity is preceded and followed by a 1.0 hour preparation and post-activity period allocated for personal hygiene. The influence variables for this activity are start time and stop time.

3.21.2 Payload Interface

An appropriate schedule of sleep periods must be provided for the payload personnel.

3.21.3 Data Sources

Same as for eat periods (3.20).

3.21.4 Data Requirements

Same as for eat periods (3.20).

3.22 WASTE MANAGEMENT

3.22.1 Description

The objective of this activity is that of providing for the waste management functions of the crew onboard the Shuttle. The influence variables for this activity are start time and stop time.

3.22.2 Payload Interface

Appropriate provisions for payload personnel waste management processes are required.

3.22.3 Data Sources

Neither automated nor sortie payload data classifies this activity as a payload personnel skill and have not made provisions for such an entry.

3.22.4 Data Requirements

The current version of the Mission Planning Processor requires a profile of the waste management activity for the payload personnel.

3.23 APU CHECKOUT

3.23.1 Description

The function of the Auxiliary Power Units (APUs) is to provide mechanical shaft power to drive hydraulic pumps for the operation of the aerosurface controls, main engine gimbal, landing gear, main wheel brakes, and nosewheel steering. The APUs are used during prelaunch, ascent, entry, and landing, and these operations are included in the Flight Common Activity. The objective of this activity is to provide for the checkout of the APU in addition to and independently of the operations already included in the Flight Common Activity. The influence variables for this activity are start time and stop time.

3.23.2 Payload Interface

This is an Orbiter operational activity with no direct interface to the payload. Payload functions which are conflicting with this activity cannot be conducted concurrently.

4.0 RECOMMENDATIONS

4.1 MISSION PLANNING PROCESSOR

The review of payload interface to the Mission Planning Processor results in the recognition of several features which are suggested as modifications to future versions of the Processor for improved interface.

1. The EVA and IVA activities represent situations in which the life support consumables for the subject(s) are provided by the Orbiter. There are no provisions for transfer to or from a payload which provides such life support such as a manned Tug. Provisions for such a payload interface should be incorporated.

2. Deployment or retrieval of a payload of significant weight affects the propulsion consumables requirement to accomplish subsequent ΔVs of the Orbiter. Provision for such a weight change on-orbit should be incorporated in the Mission Planning Processor. It is suggested that this feature be incorporated in the manipulator operations activity as an additional input specifying the magnitude and sense of the weight change.

3. The terminology "downlink" and "uplink" imply communication with the ground. In view of the requirements for Orbiter communications to or from the ground, TDRS and/or an automated payload, the respective activities would be more descriptive if renamed "transmit" and "receive".

   In addition, an indication of attitude hold requirements for these communications activities should be incorporated in the input and reflected in the associated consumables usage. Incorporation of this feature would eliminate the current multiple activity entry requirement on the part of the user.

4. The waste management activity as currently defined in the Mission Planning Processor is not a schedulable activity. In this view and with respect to the magnitude of the associated consumables, it is suggested that this activity be incorporated in the baseline (common) data base and eliminated from the activity menu.

4.2 PAYLOAD DATA SOURCE

The Mission Planning Processor is a phase/activity block oriented system with simple input as to when the phases and/or activities start and stop. Such a system is not only applicable to consumables planning, but may be viewed as the final input form of any mission planning function. Regardless

of the structure, format, manipulation requirements, or data flow, the information, whether Orbiter or payload data, ultimately ends up as a timeline of when various activities occur. Information in this form is then converted to response of spacecraft measurable consumables related parameters in support of flight operations. The consumables Mission Planning Processor is designed to perform this latter conversion with the view that the end object of mission planning is support of flight operations.

The defined process and end item should be considered in the establishment of an authoritative payload data base, not only for the consumables Mission Planning Processor, but also with respect to other mission planning functions. The following proposes the steps and generic contents of a payload data base system which would satisfy this goal.

1. Establish a standardized set of operational phases and activities.
2. Develop a payload data base format which contains user input requirements and a timeline of associated phases and activities.
3. Develop a data control and manipulation process which converts user defined requirements (principal investigator input) to the subject timeline of associated phases and activities. (Store in data base.)
4. Provide access to the timeline data to various mission planning functions. These data should reflect the best estimate of this timeline at any stage of the planning cycle so that the respective function's operational parameters may be established.
5. Provide feedback to the principal investigator through a combination of items 3 and 4 to reflect conflicts and possible modifications of requirements.

REFERENCES

1. "Formulation of Detailed Consumables Management Models for the Development (Preoperational) Period of Advanced Space Transportation Systems," Volume I, Detailed Requirements for the Mission Planning Processor, TRW Technical Document No. 26821-H002-R0-00, November 1976.

2. Payload Descriptions, Volume I, Automated Payloads, NASA/MSFC, July 1974.

3. Payload Descriptions, Volume II, Sortie Payloads, NASA/MSFC, July 1975.

APPENDIX A

TYPICAL AUTOMATED PAYLOAD DATA

AUTOMATED PAYLOAD
DEFINITION AND REQUIREMENTS DATA
LEVEL B

PAYLOAD NAME EXTENDED X-RAY SURVEY

PAYLOAD NO. HE-03-A

SHEET NO.	TITLE
*A-1	MISSION DEFINITION PARAMETERS
*A-2	OBJECTIVES
A-3	MISSION EQUIPMENT — CHARACTERISTICS
A-4	MISSION EQUIPMENT — ELECTRICAL POWER AND DATA
A-5	SUPPORTING SUBSYSTEMS — CHARACTERISTICS
A-6	MISSION AND SUBSYSTEM EQUIPMENT — ENVIRONMENTAL LIMITS: NON-OPERATING
A-7	MISSION AND SUBSYSTEM EQUIPMENT — ENVIRONMENTAL LIMITS: OPERATING
A-8	IN-FLIGHT CONTAMINATION CONTROL CRITERIA
A-9	ON-ORBIT CHECKOUT/MONITOR/CONTROL EQUIPMENT
A-10	SKETCHES (TOTAL SPACECRAFT WEIGHTS)
*A-11	MISSION OPERATIONS
*A-12	ON-BOARD TEST, CHECKOUT AND DEPLOYMENT REQUIREMENT
*A-13	PAYLOAD ELECTRICAL POWER REQUIREMENTS
*A-14	DATA AND COMMUNICATIONS CHECKOUT AND DEPLOYMENT SUPPORT
*A-15	DATA AND COMMUNICATIONS CHECKOUT AND DEPLOYMENT SUPPORT/ON-ORBIT OPERATIONS SUPPORT
A-16	PAYLOAD ENVIRONMENTAL LIMITS
*A-17	PAYLOAD PERSONNEL SKILL REQUIREMENTS
A-18	LAUNCH/LANDING SUPPORT REQUIREMENTS
A-19	GROUND FACILITY REQUIREMENTS
A-20	GROUND ENVIRONMENTAL LIMITS
A-21	PAYLOAD SAFETY ANALYSES

* Included in this appendix

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AUTOMATED PAYLOAD
MISSION DEFINITION PARAMETERS

DATA SHEET NO. A-1 PAYLOAD NO. HE-03-A
DATE 9 June 1974 REV DATE ______ LTR ______

PAYLOAD NAME Extended X-ray Survey

GENERAL PROGRAM/PAYLOAD INFORMATION

1. Discipline High Energy Astrophysics
2. Cognizant Scientist/Engineer Dr. A. Opp
3. Development Agency NASA/OSS 4. Launch site ETR
5. Delivery Mode ☒ Shuttle Only ☐ Shuttle plus Tug
6. Initial Launch Date Opening (month/day/year) 1982 7. Launch window duration N/A days
8. Program lifetime (years) 4
9. Continuation of Expendable Launched Mission ☒ no ☐ yes
10. No. of New-buy Spacecraft · Developmental 1 11. Operational 1
12. No. of Spacecraft Operating Simultaneously 1
13. Spacecraft Design Lifetime (months) 24 (2)
14. On-orbit Servicing and Repair ☐ no ☒ yes 15. Service/Repair Interval (months) 24
16. Return and Refurbish ☐ no ☒ yes 17. Refurbish Interval (months) 48
18. Payload Weight Launched (kg) 8011 19. Payload End-of-Life Weight (kg) 7457

Payload Overall Dimensions (m)

20. Ascent mode 4.57 dia. × 5.72
21. Deployed mode 4.57 × 10 × 7.55

22. Stabilization ☒ 3-axis ☐ Spin ☐ Other N/A 23. Spin rate N/A RPM

Orientations: 24. Shuttle Stellar (1) 25. Tug N/A

26. Separation tipoff rates (deg/sec max. allowable) P 0.0083 Y 0.0083 R 0.0083

27. Velocity Pkg. ☐ Apogee kick or injection N/A m/sec ΔV ☐ SEP N/A kW(e)

☐ Planetary (type) N/A

LAUNCH SCHEDULE/TRAJECTORY SUMMARY

Data Item No.	28-31	32-35	36-39	40-43	44-47	48-51	52-55	56-59	60-63	64-67	68-71	72-75	76-79
Launch Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
No. of Launches – Delivery				1									
No. of Launches – Retrieval								1					
No. of Launches – Service					1		1						
Mission Launch Code (Letter)				A	A		A	A					

Orbital Parameters		A	B	C	D	E
80. Apogee (km):	Desired	370				
81.	Minimum	352				
82.	Maximum	389				
83. Perigee (km)	Desired	370				
84.	Minimum	352				
85.	Maximum	389				
86. Inclination (deg)	Desired	28.5				
87.	Minimum	28				
88.	Maximum	30				
89. ΔV from Tug above 160 n. mi. circ (km/sec) or 90. C_3 (km^2/sec^2)		N/A				
91. Declination of Launch Asymptote (deg) 92. Orbital Position Longitude (deg) 93. Tolerance (deg)		N/A				

94. Does Spacecraft have capability to reposition itself in orbit after separation from Tug? ☐ yes ☐ no

3σ Placement Accuracy (Geosynch Orbit Only)

	Component: Radial	Tangential	Normal
95. Position, km	N/A	N/A	N/A
96. Velocity, m/sec	N/A	N/A	N/A

REFERENCE DOCUMENTS: 98. Source Payload Model Date Oct. 1973 99. Code No. AST-5

97. a. Volume 3 High Energy Astrophysics, Final Report of the Space Shuttle Working Groups, May, 1973.
b. Document ASE 2266A, Preliminary Study; Telescopes and Scientific Systems for a High Energy Astronomy Observatory, Revision 26 September 1967.
c. Woods Hole Summer Study Group, July 1973.

100. NOTES: (1) Bay such that line of sight exists toward TDRS.
(2) Basic spacecraft design is sufficient for 120 months lifetime with servicing at 12 to 24 month intervals and refurbishment at 5 year interval.

101. GENERAL COMMENTS

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AUTOMATED PAYLOAD
OBJECTIVES

DATA SHEET NO. A-2 PAYLOAD NO. HE-03-A
DATE 9 June 1974 REV DATE ______ LTR ______

PAYLOAD NAME Extended X-Ray Survey

1. SUMMARY:
This payload supports the study of spatial properties of galactic and extragalactic X-ray sources over the entire accessible energy range for such observations, 0.03 to 300 keV. The instruments, although not requiring extremely precise absolute pointing, do impose a uniformly stringent stability requirement of an arc-second on the shuttle for accomplishment of their objectives. The important objective of source localization will require absolute aspect determination in the arc-second or sub-arc-second range The instrument design will allow convenient modification of collimation properties between flights to allow optimal measurements for the particular flight objectives.

2. MISSION OBJECTIVES:

The basic objectives of this mission are to provide moderate angular resolution measurements of X-ray sources. The ultimate resolution depends upon the energy band of interest with the most precise measurements (about 1 arc-sec) being in the 0.03 to 1 keV band in which focusing techniques are used. At higher energies, modulation collimators with various field of view characteristics are used. At the highest energies (~ 300 keV) measurements are limited by collimation efficiency and source strength to a fraction of an arc-minute.

3. RELATIONSHIP TO DISCIPLINE OBJECTIVES:
The objectives of this mission concern the spatial properties of various types of X-ray emitters over a very wide range of energies, roughly 0.03 to 300 keV. Such information is crucial in the study of certain objects for which the energy content is diffused over an extensive volume. In some cases, a notable example being clusters of galaxies, the spatial structure of the X-ray emission offers the only hope of understanding the dynamics and evolution of the system. The other major objective, source localization, is essential to the discovery of X-ray counterparts of optical and radio sources, so that complete spectral and temporal characteristics can be determined.

EXPERIMENTS

4. No.	5 Title	6. Objectives
XHE310	Angular Structure Observations (All Instrumentation)	Determine angular structure of extended sources such as super-nova remnants and clusters of galaxies Precision of such measurements to vary from 1 arc-sec to several arc-min. depending on energy range.
XHE312	Galactic Medium Studies (Low Energy X-Ray Telescope)	Provide positional data on point sources sufficient to allow identification with optical or radio objects. Nominal accuracy requirement is 5 arc-sec. Maximum sensitivity available in 0.03 to 1 keV band.
XHE314	Intergalactic Medium Studies Low Energy X-Ray Telescope	Detect the intergalactic medium by observation of absorption features in spectra of extragalactic sources in 0.03 to 1 keV spectral range.
XHE320	Source Localization (Primarily Proportional Counter Array)	Map selected regions of the galactic plane in energy range 0.03 to 1 keV. Specific measurements include spectral features such as K and L absorption edges and scattering from interstellar grains. Secondary data with Scintillation Counter Array
XHE321	Moderate Sensitivity Sky Survey (Imaging Proportional Counter)	Search selected regions of the sky for X-ray sources to a limiting intensity of 10^{-7} Sco X-1 using high efficiency, moderate resolution detectors.

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AUTOMATED PAYLOAD
MISSION OPERATIONS

DATA SHEET NO. A-11 PAYLOAD NO. HE-03-A
DATE 9 June 1974 REV DATE ______ LTR ____

PAYLOAD NAME Extended X-Ray Survey

Phase No.	Phase Name	Operations	Mission Times ①, Hours → (SCALE AS REQUIRED) × 24 = Days (-2, -1, 0, 1, 2, 3, 4, 5, 6, 7, 8)
1.	Launch Pad/ Liftoff	Prepare for launch, maintain environment, top off consumables.	48 hrs.
2.	Ascent (Shuttle)	Maintain payload environment (1)	② 6 hrs.
3.	On-Orbit Deployment (Shuttle)	Further activate, checkout, test, prepare for deployment. Deploy or release in orbit. (2) Standby, monitor, maintain readiness for recovery or backup control. Contingency recycle time.	24 hrs. Up to 6 hrs. 48 hrs. 120 hrs potential escort mode 72 hrs.
4.	Ascent (OOS/Tug)	N/A	
5.	On-Orbit Deployment (OOS/Tug)	N/A	
6.	On-Orbit (Operational)		
7.	Retrieval (By OOS/Tug)	N/A	
8.	Descent (OOS/Tug)	N/A	
9.	Retrieval (By Shuttle)	Backup preparation for docking by commanding payload cover closure, retraction of solar arrays & TDRS antenna. Assist in rendezvous and payload recovery.	6 hrs.
10.	Descent (Shuttle)	Monitor and control payload environment.	③ 6 hrs.
11.	Landing/ Post-Landing (Through PL Removal)	Monitor and control payload environment until payload is returned to its clean room	Up to 36 hrs.

PREPARATION INSTRUCTIONS:
① Mark discrete events (liftoff, separation, landing) by ▽
Use bars ▭ to show time intervals.
② Nominal Shuttle ascent phase time is 1 hour.
③ Nominal Shuttle descent phase time is 1 hour.

NOTES.
(1) Total time to obtain desired orbit including orbital altitude and plane change plus time to attain orbital checkout mode, including TDRS contact.
(2) Options: Launch may be completed in 30 hours, or problems may delay completion up to 150 hours.

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AUTOMATED PAYLOAD

ON-BOARD TEST, CHECKOUT AND DEPLOYMENT REQUIREMENTS

PAYLOAD NAME Extended X-Ray Survey

DATA SHEET NO. A-12 PAYLOAD NO. HE-03-A
DATE 10 June 1974 REV DATE ___ LTR ___

Phase No.	Phase	MISSION AND SUBSYSTEM EQUIPMENT — 1. Inv. No.	MISSION AND SUBSYSTEM EQUIPMENT — 2. Name	3. TEST, CHECKOUT, AND DEPLOYMENT REQUIREMENTS. (Incl special orientation, pointing, communications, etc.)	4. Pointing/Stability Required during Checkout and/or Deployment	5. Support Required	6. Notes
1.	Launch Pad/ Liftoff	HE335 SS010	Control/Display/Test Unit, Science Payload Control/Display/Test Unit, Support Systems Module	Monitor and control environment and status of sceintific payload		Provide cooling, electrical power, telemetry, via ground support equipment.	
2.	Ascent (Shuttle)	HE335 SS010	Cntrl/Display/Test Unit, Instr. Cntrl/Display/Test Unit, SSM	Monitor and control environment		Shuttle provides power, venting, telemetry, recording during ascent.	
3.	On-Orbit Deployment (Shuttle)	HE310-HE315 HE321-HE322 HE331-HE332 HE335 SS010	Telescope, instrument, and electronics. Proportional Counter Array + electronics. High Energy X-ray Survey Instrument Cntrl/Display/Test Unit, Instr. Cntrl/Display/Test Unit, SSM	Activate, checkout, test, adjust and calibrate telescopes, instruments, proportional counter array, and high energy X-ray survey cluster Activate, checkout, test, and adjust subsystem support module. (1) Release or deployment	Accuracy 1800 sec Duration 12 hr Stability 1800 sec Duration 12 hr Stability Rate 30 sec/sec	Earth based control center checkout, test, diagnosis, calibration, automated and manual operations. Assist from shuttle orbiter onboard payload and flight crew specialists as necessary.	(1) Guidance and navigation reference angle transfer.
4.	Ascent (OOS/Tug)	N/A	N/A	N/A		N/A	
5.	On-Orbit Deployment (OOS/Tug)	N/A	N/A	N/A	Accuracy N/A sec Duration N/A hr Stability N/A sec Duration N/A hr Stability Rate N/A sec/sec	N/A	
6.	On-Orbit (Operational)						
7.	Retrieval (By OOS/Tug)	N/A	N/A	N/A		N/A	
8.	Descent (OOS/Tug)	N/A	N/A	N/A		N/A	
9.	Retrieval (By Shuttle)	Payload HE335 SS010	Cntrl/Display/Test Unit, Instrs Cntrl/Display/Test Unit, SSM	Command power down of science instruments, close protective covers, retract solar arrays and TDRS antenna. Control payload rendezvous and recovery. (2)		Payload specialist and shuttle orbiter flight crew	(2) If malfunction requiring recovery and repair
10.	Descent (Shuttle)	HE335 SS010	Cntrl/Display/Test Unit, Instrs Cntrl/Display/Test Unit, SSM	Monitor and control environment, provide clean repressurization		Clean repressurization gases, telemetry, recording, heat sink	
11.	Post-Landing (Through PL Removal)	HE335 SS010	Cntrl/Display/Test Unit, Instrs. Cntrl/Display/Test Unit, SSM	Monitor and control environment		Ground support, clean air and cooling unit.	

GENERAL COMMENTS:

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AUTOMATED PAYLOAD

PAYLOAD ELECTRICAL POWER REQUIREMENTS
(At Shuttle System Interface)

PAYLOAD NAME Extended X-Ray Survey

DATA SHEET NO. A-13 PAYLOAD NO. HE-05-A
DATE 11 June 1974 REV DATE ______ LTR ______

			D.C. POWER									A.C. POWER									
		1 Mission Phase Duration (hr)	Voltage		Avg. Power		Peak Power			9 Energy per Phase (kWh)	10 Source Freq. (Hz)	Voltage		Avg. Power		Peak Power			18 Energy per Phase (kWh)	19 Total Energy per Phase (kWh)	20 Notes
Phase No.	Phase		2 Nom. (V)	3 Tol. (±%)	4 Level (W)	5 Dur. (hr)	6 Level (W)	7 Dur. (hr)	8 Repetition Rate			11 Nom. (V)	12 Tol. (±%)	13 Level (W)	14 Dur. (hr)	15 Level (W)	16 Dur. (hr.)	17 Repetition Rate			
1.	Launch Pad/ Liftoff	48	28	1	100	Up to 48	N/A	N/A	N/A	4.8	N/A								N/A		
2.	Ascent (Shuttle)	6			100	6	N/A	N/A	N/A	0.6	N/A								N/A	0.6	
3.	On-Orbit Deployment (Shuttle)	156		(1) (2) (3)	1311.3 300 300	48 3 96	1361 N/A N/A	0.3 N/A N/A	1 per 1.5 hr. N/A N/A	62.9 0.9 28.8	N/A N/A N/A								N/A N/A N/A	Shuttle 92.6 Tug N/A	(1) Checkout & test (2) Release & deploy (3) Escort mode
4.	Ascent (OOS/Tug)	N/A																	N/A	N/A	
5.	On-Orbit Deployment (OOS/Tug)	N/A																		N/A	
6.	On-Orbit (Operational)																				
7.	Retrieval (By OOS/Tug)	N/A																		N/A	
8.	Descent (OOS/Tug)	N/A																		N/A	
9.	Retrieval (By Shuttle)	6			300	6	N/A	N/A	N/A	1.8	N/A								N/A	1.8	
10.	Descent (Shuttle)	6			100	6	N/A	N/A	N/A	0.6	N/A								N/A	0.6	
11.	Landing/ Post-Landing (Through PL Removal)	36	28	1	100	Up to 36	N/A	N/A	N/A	3.6	N/A								N/A		

21 GENERAL COMMENTS·

22 Total inflight energy from Shuttle 93.2 kW-hr } Ascent Phases
23 Total inflight energy from Tug N/A kW-hr } 2 thru 5 only

SSPD (A-13) 4-30-74

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AUTOMATED PAYLOAD
DATA AND COMMUNICATION
CHECKOUT AND DEPLOYMENT SUPPORT

PAYLOAD NAME Extended X-Ray Survey

DATA SHEET NO. A-14 PAYLOAD NO. HE-03-A
DATE 11 June 1974 REV DATE ____ LTR ____

PHASE		OPERATION		COMMAND SYSTEM			DATA ACQUISITION					DATA DISPOSITION				15
No.	Name	1 Description. Separate mission equipment ops from support subsystem ops	2 Duration, hrs	3 From: GSE Orbiter Tug Ground Net TDRS Other	4 Link: Hardwire or RF	5 Data Req't Command Type & Rate	6 To GSE Orbiter Tug Ground Net TDRS Other	7 Type Digital, Analog Film TV Voice	8 Acquis. Link: S-band Ku-band Hardwire Manual	9 Acquisition Rate in bps, Hz, fps, channels	10 Total Data Quantity bits, time & bw, time, frames	11 Stored & Returned Quantity	Transmit Real Time 12 Rate	Transmit Real Time 13 Duration hrs	Transmit Playback 14 Quantity	Notes
1.	Launch Pad/ Liftoff	Monitor and control environment and status. Prepare for launch.	Up to 48	GSE	Hardwire	PSK, D, 128 bps	GSE	D	Hardwire	512 bps	8 847E08	8.847E08	N/A	N/A	N/A	
2.	Ascent (Shuttle)	Monitor and control environment.	6	Orbiter	Hardwire	PSK, D, 128 bps	Orbiter	D	Hardwire	512 bps	1.106E07 bits	1.106E07 bits	N/A	N/A	N/A	
3.	On-Orbit Deployment (Shuttle)	Backup activation, checkout, test, calibration	48	TDRS (2)	RF	PSK, D, 2048 bps	TDRS	D	S-band	64816 bps	1.12E10 bits	1 12E10 bits	1E06 bps	3.1	1.12E10 bits	(1) Solar array & TDRS antennas retracted.
		Release & deploy payload (1)	3	Orbiter	RF	PSK, D, 2048 bps	Orbiter	D	S-band	512 bps	5 53E06 bits	5.53E06 bits	1E06	0.0015	5.53E06 bits	(2) Also routed to displays and recorder onboard Shuttle orbiter.
		Escort, back monitor and readiness to aid or recover	96	TDRS (2)	RF	PSK, D, 2048 bps	TDRS	D	S-band	64816 bps	2.24E10 bits	2 24E10 bits	1E06 bps	6.22	2.24E10 bits	
							TDRS	TV		Total	3.36E10 bits 1.5 hr			1.5		
4.	Ascent (OOS/Tug)	N/A													N/A	
5.	On-Orbit Deployment (OOS/Tug)	N/A													N/A	
6.	On-Orbit Operational															
7.	Retrieval (By OOS/Tug)	N/A													N/A	
8.	Descent Tug	N/A													N/A	
9.	Retrieval (By Shuttle)	Command payload to power down, retract solar arrays, & TDRS antennas. Rendezvous and recover.	6	Orbiter	RF	PSK, D, 2048 bps	Orbiter	D	S-band	2048 bps	4.424E07 bits	4.424E07 bits	1E06 bps	0 012	4 42E07	Optional if malfunction and recovery desired
10.	Descent (Shuttle)	Monitor and control environment, repressurize	6	Orbiter	Hardwire	PSK, D, 2048 bps	Orbiter	D	Hardwire	512 bps	1.106E07 bits	1.106E07 bits	N/A	N/A	N/A	
11.	Landing/Post-Landing (Through PL Removal)	Monitor and control environment	Up to 36	Orbiter + GSE	Hardwire	PSK, D, 128 bps	Orbiter + GSE	D	Hardwire	512 bps	6.636E07 bits	6.636E07 bits	N/A	N/A	N/A	

GENERAL COMMENTS:

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AUTOMATED PAYLOAD
DATA AND COMMUNICATIONS
CHECKOUT AND DEPLOYMENT SUPPORT/ON-ORBIT OPERATIONS SUPPORT

PAYLOAD NAME Extended X-Ray Survey

DATA SHEET NO. A-15 PAYLOAD NO. HE-03-A
DATE 11 June 1974 REV DATE ______ LTR ______

Phase No.	Phase Name	OPERATION: 1 Description (Separate mission equipment ops from support system ops)	2 Duration, hrs	3 LOC: Orbiter, Tug, Ground Control (Exclude GSE)	CONTROL DISPLAY: 4 Control Equipment — Type & Quantity	5 Monitor & Displays — Type & Quantity	COMPUTER SUPPORT: 6 Functions	7 Word Length	Memory Req't (words): 8 Rapid Access	9 Bulk	10 Opers. per Sec.
1	Launch Pad/ Liftoff	Monitor and control environment & status, prepare for launch	Up to 48	GSE	2 Auto. monitor & control units, one for X-ray payload, one for SSM.	Malfunction alphanumeric readout with parallel GSE output for verif.	Auto. monitor & control of environment with manual override.	32	8E03	5E04	2E03
2.	Ascent (Shuttle)	Monitor and control environment	6	Orbiter	2 Auto. monitor & control units	2 Auto monitor, alarm, & critical item readout.	Auto. monitor & control with manual override	32	8E03	5E04	2E03
3.	On-Orbit Deployment (Shuttle)	Backup activation, checkout, test, diagnosis Release and deployment Escort monitoring, readiness for backup control and recovery.	48 3 96	Ground control + backup by Orbiter Orbiter Ground Control, Orbiter	One auto. monitor/ control unit for X-ray telescope arrays, instruments. One auto. control unit for SSM with manual override	Detailed multi-function displays at ground control backed up by on-board multifunction alphanumeric read-out on two monitor/ control consoles.	Backup auto. monitor and control of check-out, test, alarm circuits, enabling readiness for active control, rendezvous, retrieval, recycling, etc.	32	3.2E04	2.5E05	1E04
4.	Ascent (OOS/Tug)	N/A									N/A
5.	On-Orbit Deployment (OOS/Tug)	N/A									N/A
6.	On-Orbit Operational										
7.	Retrieval (By OOS/Tug)	N/A									N/A
8.	Descent (OOS/Tug)	N/A									N/A
9.	Retrieval (By Shuttle)	Command payload to power down, retract solar arrays & TDRS antennas. Rendezvous & retrieval.	6	Orbiter	2 Auto. monitor & control units with manual override; one for instruments; one for SSM	2 Multifunction alphanumeric + symbol readout	Auto monitor & control of payload with override in recovery operations	32	1.6E04	1E05	4E03
10.	Descent (Shuttle)	Monitor & control environment (a)	6	Orbiter	2 Auto. monitor & control units	2 Auto. monitor & control units	Auto. monitor & control of environment	32	8E03	5E04	2E03
11.	Landing/ Post-Landing (Through PL Removal)	Monitor & control environment (a)	Up to 36	Orbiter + GSE	2 Auto. monitor & control units	2 Auto. monitor & control units	Auto. monitor & control with manual override	32	8E03	5E04	2E03

11. GENERAL COMMENTS: (a) If critical component malfunction not repairable in space.

MISSION OPERATIONS SUPPORT REQ'TS (ON-ORBIT OPERATIONAL PHASE)

Network Facilities Req'd
1 STDN ☐
2 TDRS ☒
3 DSN ☐
4 ESRO ☐
5 CNES ☐
6 Other ______

Length of Support Req'd
7 Launch only ☐
8 Launch/Early Orbit Only ☐
9 Mission Lifetime ☒

Telemetry Support
Real Time Data
Frequency Bands/Data Rate (bps or)
10 57172 bps
11 4096 bps
12 1E06 bps
13 ______
Volume (Analog, Time; Digital, bits/day)
14 5246.2 Mbits/day
15 353.8 Mbits/day
Playback Data
Freq. Bands/Data Rate (bps)
16 57127 bps
17 4096 bps
18 1E06 bps
19 ______
Volume (Analog, Digital)
20 5246.2
21 353.8
Times
22 Min. Acceptable Contact Time TBD Minutes
23 Max. Allowable Gap Time TBD Minutes

Tracking Support
24 Type (C-band, S-band, Other) S-band

25 Accuracy Req'd TBD

Orbit Determination Accuracy (xyz)
26 Position, km 1, 1, 1
27 Velocity, m/s 1, 1, 1

Special Support
28 Attitude Determination Accuracy 0.01667 degrees
29 Timing Accuracy 1E-06 sec
30 Ground Time Updates Req'd ☒ Yes ☐ No

Command System
31 Freq. or band S-band
32 Rate 2048
33 Word Length 32
34 Rejection Rate TBD
35 Type (Tone, Tone/Digital, PCM, Other) PSK

Control Center (CC) Communication
36 Real Time Transmission Rate from Remote Site to CC 57172 bps
37 TLM playback data req'd at CC ☒ Yes ☐ No
38 Likely CC Location (GSFC, ARC, JPL, Other) TBD

Experiment Data Processing Req'd
39 ☒ Yes ☐ No
40 Explain Spatial image & dynamic range enhancement, rejection of spurious radiation interference.

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AUTOMATED PAYLOAD
PAYLOAD PERSONNEL SKILL REQUIREMENTS

PAYLOAD NAME Extended X-Ray Survey

DATA SHEET NO. A-17 PAYLOAD NO. HE-03-A
DATE 11 June 1974 REV DATE ____ LTR ____

Mission Phase: Phase No.	Mission Phase: Phase	1 Checkout, Deployment, Retrieval Operations	Skills Required: 2 Role (Type)	Skills Required: 3 Field (Specify)	Location: 4 CABIN	Location: 5 IVA	Location: 6 EVA	Specific Task: 7 Description	Time Req'd (Manhours) per Role/Field: Per Task: 8 EVA or IVA	Per Task: 9 Total	Per Phase: 10 EVA or IVA	Per Phase: 11 Total	12 Contingency EVA/IVA ?
1	Launch Pad/ Liftoff	Monitor and control payload environment (1)	Technician	High Energy Astrophysics	X	N/A	N/A	Monitor temperature, pressure, and other environmental parameters Override automatic control as necessary to protect equipment.		Up to 48		Up to 48	
2	Ascent (Shuttle)	Monitor and control environment	Technician		X			Monitor & control environment (pressure, temp., venting)		6		6	
3	On-orbit Deployment (from Shuttle)	Backup activation, checkout, test, alignment, calibration.	Technician		X			Provide backup monitoring, maintain readiness to aid ground controlled checkout & test (2)	0	24	0	48	Yes
			Technician		X				0	24	0		Yes
		Support release & deployment	Technician		X			Prepare release & guide payload	0	3	0	3	No
		Provide escort mode backup/monitoring, maintain readiness to assist ground control; retrieval, etc.	Technician		X			Via control/display/test units	0	3	0	3	No
			Technician		X			Monitor and assist ground controlled checkout (3)	0	48	0	96	No
			Technician		X				0	48	0		
9	Retrieval by Shuttle	Command payload to reduce power, retract solar arrays and TDRS antennas. (4)	Technician		X			By remote command, close telescope and instrument aperture covers, reduce power level to a min., retract solar arrays and TDRS antenna.	0	6	0	12	No
		Command payload to hold rendezvous and docking attitude. Rendezvous and recover (4)	Astronaut		X			Assist shuttle orbiter pilot in rendezvous and recovery of payload.	0	6	0		No
10	Descent (Shuttle)	Monitor and control payload environment (5)	Technician		X			Monitor and control environment, incl. pressurization		6		12	
			Technician		X					6			
11	Landing/ Post-Landing (Through PL Removal)	Monitor and control environment	Technician		X			Monitor pressure, temperature, humidity within payload elements, maintain differential + pressure with respect to outside of instrument or telescope environment.		18		36	
			Technician		X	N/A	N/A			18			

13 Notes

(1) May be accomplished by ground based personnel at GSE after verification of control from Shuttle Orbiter cabin.

(2) Contingency EVA of 3 ea. 4-hour EVAs, if necessary.

(3) One man per shift: 2 48-hour periods one after the other.

(4) If malfunction not resolvable by remote control.

(5) If malfunction not repairable in space.

(6) One man on duty per shift.

18 GENERAL COMMENTS (a) One shift for first task of phase No. 3, two shifts for second and third tasks of phase No. 3.
(b) Delivery of payload might be completed in half the total time. Estimates above allow a complete recycle

Total Mission Skill Hours 13 156 delivery (phases 2, 3)
14 24 retrieval (phases 9, 10)

15 No. of Planned EVA 0
16 Avg Duration of EVA N/A hr.
17 PL Personnel Operation: ☐ 1 Shift ☒ 2 Shifts (a)

APPENDIX B

TYPICAL SORTIE PAYLOAD DATA

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SORTIE PAYLOAD
DEFINITION AND REQUIREMENTS DATA
LEVEL B

PAYLOAD NAME DIAGNOSTIC PAYLOAD

PAYLOAD NO. AP-11-S

* Included in this appendix.

SSPD (S-0) 3-15-74

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MISSION DEFINITION PARAMETERS

DATA SHEET NO. S-1 PAYLOAD NO. AP-1-S
DATE 3-31-75 REV DATE ____ LTR ____

PAYLOAD NAME DIAGNOSTIC PAYLOAD

1. Discipline ATMOSPHERIC AND SPACE PHYSICS
2. Cognizant Scientist/Engineer TBD
3. Development Agency NASA
4. Initial Launch Date (Year) 1980

5. No. of Sets of Mission Equipment in Program — Development TBD
6. No. of Sets of Mission Equipment in Program — Operations TBD
7. No. of Sortie Flights in Program 1
8. Nominal Flight Duration (N), days 7

LAUNCH SCHEDULE:

Data Item No.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.
Year.	79	80	81	82	83	84	85	86	87	88	89	90	91
No. Launches:													
Mission Code Letter:													

ORBIT PARAMETERS:

MISSION CODE LETTER	A	B	C	D	E	F
APOGEE, km						
22. Desired	250					
23. Minimum	120					
24. Maximum	1500					
PERIGEE, km						
25. Desired	250					
26. Minimum	120					
27. Maximum	1500					
INCLINATION, deg						
28. Desired	57					
29. Minimum	0					
30. Maximum	105					
31. Launch Site(s)	ETR					

32. Launch Window Center N/A
(Initial Launch Date/Time)
33. Launch Window Duration, hr.

PAYLOAD SUMMARY DATA.

34. Payload weight at launch, kg 692 + Launcher
35. Weight of expended consumables and P/L Equipment not returned to earth, kg 605
36. Consumables weight at launch, kg 168
37. Pressurized equipment volume, m^3 0.153
38. Estimated pallet length, m 3
39. No. of subsatellite deployments per flight 1
40. No. of subsatellite retrievals per flight 0
41. No. of planned EVAs per flight 0
42. Average duration of each EVA, hr 0
43. Preferred accommodation mode MODULE/PALLET

☐ Pallet only: on-orbit control ☐, control from ground ☐
☐ Lab only
☒ Lab plus pallet

44. Payload Model Date
45. P/L Code No.

46. REFERENCE DOCUMENTS:

47. COMMENTS.

SORTIE PAYLOAD
OBJECTIVES

PAYLOAD NAME DIAGNOSTIC PAYLOAD

DATA SHEET NO. S-2 PAYLOAD NO. AP-[illegible]-S
DATE 3-31-75 REV DATE ______ LTR ______

1. SUMMARY.

THIS PAYLOAD CONSISTS OF A MANEUVERABLE SUB-SATELLITE SUCH AS AN ATMOSPHERIC EXPLORER INSTRUMENTED WITH ELECTRIC AND MAGNETIC FIELD DETECTORS, AN X-RAY TELESCOPIC AND SEVERAL PLASMA MEASURING DEVICES. THE SUBSATELLITE WILL BE LAUNCHED FROM THE SHUTTLE, MAKE MEASUREMENTS FOR MOST OF THE MISSION AND THEN BE RETRIEVED.

2. MISSION OBJECTIVES.

THE PRIMARY OBJECTIVE OF THIS MISSION IS TO VERIFY THE MANEUVERABLE SUBSATELLITE SYSTEM AS AN ADEQUATE DIAGNOSTIC TOOL FOR FUTURE SPACELAB EXPERIMENTS.

3. RELATIONSHIP TO DISCIPLINE OBJECTIVES

IF THE MANEUVERABLE SUBSATELLITE SATISFIES THE DIAGNOSTIC REQUIREMENTS ON THIS MISSION IT WILL BE INSTRUMENTED AND USED NEARLY CONTINUOUSLY THROUGHOUT THE SHUTTLE ATMOSPHERIC AND SPACE PHYSICS SHUTTLE PROGRAM.

EXPERIMENTS

4. No.	5 Title	6 Objectives
XAP110	SUPPORT ELECTRON ACCELERATOR	SEE AP-09-S
XAP130	SUPPORT SHUTTLE EMI	TO MAP OUT THE EMI ENVIRONMENT OF THE SHUTTLE

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SORTIE PAYLOAD
ORIENTATION, POINTING & STABILITY REQUIREMENTS

DATA SHEET NO. S-12 PAYLOAD NO. AP-11-S
DATE 3-31-75 REV DATE ____ LTR ____

PAYLOAD NAME DIAGNOSTIC PAYLOAD

EQUIPMENT		3 ORIENTATION OR TARGET(S)	4 ① Axis	SHUTTLE POINTING REQUIREMENT					MOUNT POINTING REQUIREMENT ②					FINAL INTERNAL INSTRUMENT POINTING CAPABILITY				
				Accuracy		Stability			Accuracy		Stability			Accuracy		Stability		
1 Inv. No.	2 Name			5 Level (deg)	6 Duration (hr)	7 Level (deg)	8 Duration (hr)	9 Stability Rate (deg/sec)	10 Level (sec)	11 Duration (hr)	12 Level (sec)	13 Duration (hr)	14 Stability Rate (sec/sec)	15 Level (sec)	16 Duration (hr)	17 Level (sec)	18 Duration (hr)	19 Stability Rate (sec/sec)
AP 708	3-axis Electrostatic Analyzer	Aligned with ambient B-Field (1)	X, Y	N/A	N/A	N/A	N/A	N/A	1800	1.5	900	1.5	900	1800	1.5	900	1.5	900
			Z															
AP 707	Ion Mass Spectrometer	Aligned with velocity Vector (1)	X, Y															
			Z															
AP 713	Neutral Mass Spectrometer	Aligned with velocity Vector (1)	X, Y															
			Z															
AP 705	Cylindrical Probe	Arbitrary (1)	X, Y															
			Z															
AP 715	Spherical Probe	Arbitrary (1)	X, Y															
			Z															
AP 716	X-ray Telescope	Pointing at X-ray Source (1)	X, Y							1.5		1.5						
			Z							1.5	900	1.5	900	1800	1.5	900	1.5	900
AP 711	Subsatellite Launcher	Satellite Launch Direction (2)	X, Y	1	0.5	0.5	0.5	0.05	N/A	N/A	N/A	N/A	N/A	3600	0.5	1800	0.5	180
			Z	1	0.5	0.5	0.5	0.05	N/A	N/A	N/A	N/A	N/A	3600	0.5	1800	0.5	180
			X, Y															
			Z															
			X, Y															
			Z															
			X, Y															
			Z															
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			X, Y															
			Z															
			X, Y															
			Z															

PREPARATION NOTES
① Axis Reference: Items 5-9, Use Shuttle Coordinate Axes
Items 10-19, Z is line-of-sight axis, X and Y are mutually perpendicular to Z.
② Pointing Required at Inner Gimbal.

20 GENERAL COMMENTS.
Notes
(1) Refers to Subsatellite Pointing during free flight
(2) Refers to Shuttle Pointing during Subsatellite launch

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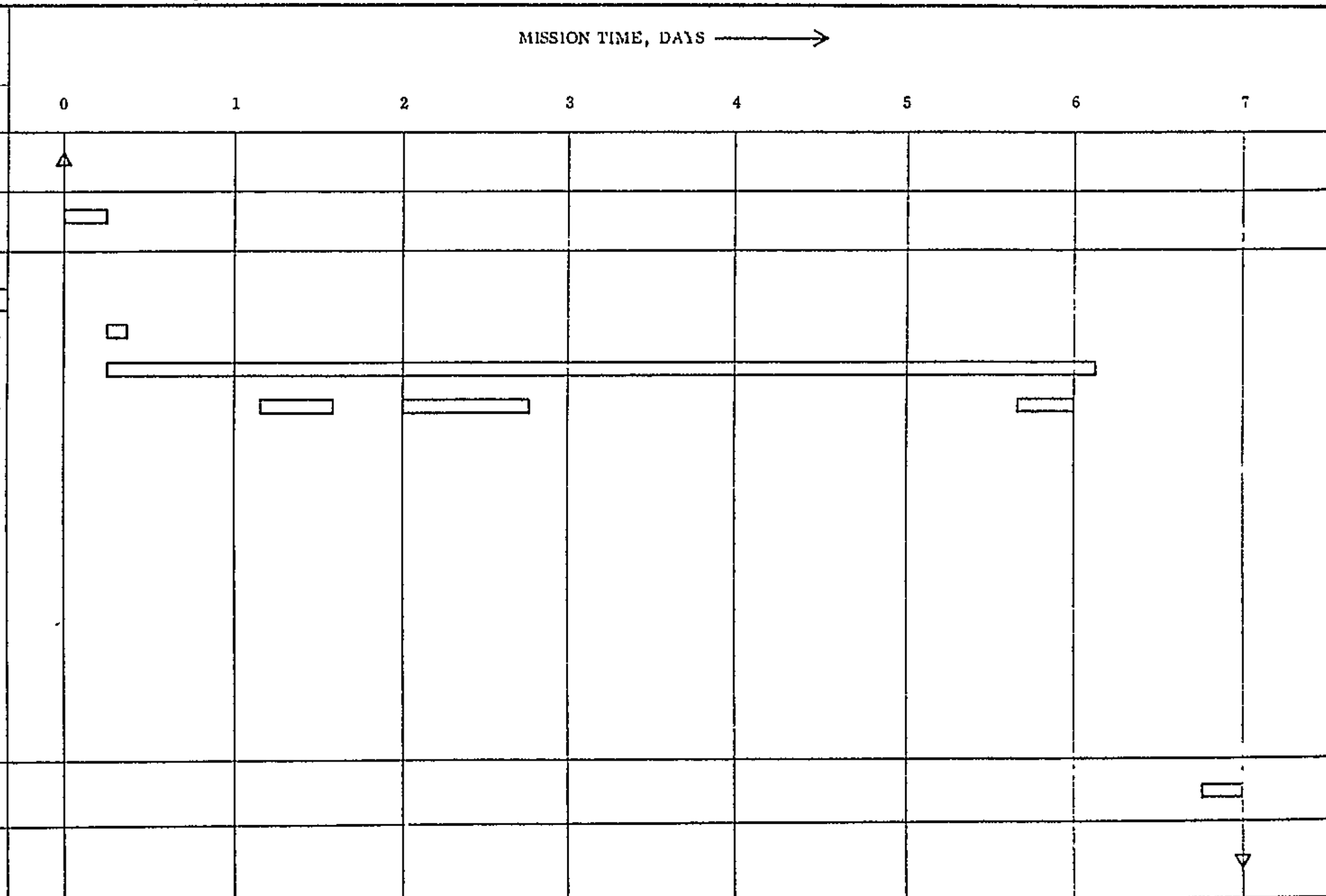
SORTIE PAYLOAD
FLIGHT OPERATIONS

DATA SHEET NO. S-13 PAYLOAD NO. [illegible]
DATE [illegible]-31-75 REV DATE ______ LTR ______

PAYLOAD NAME DIAGNOSTIC PAYLOAD

FLIGHT OPERATION			
Phase No.	Description		
1.	Lift-off		
2.	Ascent & Operational Preparation		
3.	On-Orbit Experiment Operations		
	No.	Title	
	XAP100	Launch Maneuverable Subsat.	
	XAP130	Support Shuttle EMI	
	XAP110	Support Electron Accelerator	
4.	Mission Termination & Descent		
5.	Landing		



PREPARATION INSTRUCTIONS:

1. For mission duration other than 7 days, change to appropriate time scale.

COMMENTS

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SORTIE PAYLOAD
EXPERIMENT OPERATIONAL CYCLE

DATA SHEET NO. S-14 PAYLOAD NO. AP-11-S
DATE 3-31-75 REV DATE ____ LTR ____

PAYLOAD NAME DIAGNOSTIC PAYLOAD

EXPERIMENT		INITIAL SETUP		REPETITIVE CYCLE					Repetition Rate		TERMINATION		TYPICAL TARGET ② OBSERVATION SEQUENCE				18 Notes
1 No.	2 Title	3 Function	4 Time (hr)	5 Setup & Deploy Time (hr)	6 Expt. or Observ. Dur. (hr)	7 Shut-down & Retrieve Time (hr)	8 Data Eval. Time (hr)	9 Total Cycle Time (hr)	10 No. of Cycles/ Per Day	11 No. of Cycles Per N Day Mission ①	12 Function	13 Time (hr)	14 Target Type Code ③	15 Latitude or Rt. Ascen. (deg/min /sec)	16 Longitude or Declin. (deg/min /sec)	17 Dur. Per Observ (hr)	Include viewing constraints, sin inclination angle reqmts, special slewing, etc.
XAP100	Launch Subsatellite	Launch	2	N/A									N/A				
XAP130	Support Shuttle EMI	Note (1)			6			6	1	7							(1) See AP-12-S
XAP110	Support Electron Accelerator	Note (2)															(2) See AP-09-S
		Note (3)															(3) See AP-10-S

PREPARATION INSTRUCTIONS.
① Mission duration N = 7 days.
② Specify a typical 4 to 8 orbit sequence.
③ Target Type Code.
E = Earth, location is given in latitude & longitude.
S = Stellar, location is given in right ascension and declination.
O = Other (Specify in Item 19).

19. COMMENTS. (Include statements of simultaneous operation requirements, predecessor/successor relationships, etc.).

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SORTIE PAYLOAD
PAYLOAD OPERATIONAL TIMELINE
MISSION DAY NO. 0

DATA SHEET NO. [illegible] PAYLOAD NO. [illegible]
DATE 3-[illegible]-75 REV DATE ____ LTR ____

PAYLOAD NAME DIAGNOSTIC PAYLOAD

	No.	Title	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Experiments	XAP100	Launch Subsatellite							X	X																
Experiments	XAP130	Shuttle EMI									X	X	X	X						X						X
Skills Role/Field		Technician, Electromechanical							X	X																
Skills Role/Field		Technician, Physics Plasma							X	X	X	X	X	X												X
Skills Role/Field		Experiment, Physics Plasma							X	X	X	X	X	X						X						

Time-Dependent Functions

Power Profile (kW) (at payload/Spacelab interface): AC; DC — 0, 100W, 430W, 150W, 100W, 150W, 100W, 150W

Data Profile† (at payload/Spacelab interface): Dbps — 0, 50000 bps Nominal (3E+05 bps Max); A — 0, 20 MHz

†Indicate Real Time data downlink transmission using double-width line and flag with "RT".

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SORTIE PAYLOAD

PAYLOAD PERSONNEL SKILLS & EVA/IVA REQUIREMENTS

DATA SHELT NO. S-16 PAYLOAD NO. AP-11-S
DATE [illegible]-1-75 REV DATE ______ LTR ______

PAYLOAD NAME DIAGNOSTIC PAYLOAD

EXPERIMENT		3 Functions	SKILL TYPES		P/L Personnel Time			PLANNED EVA AND IVA REQUIREMENTS				13 Contingency EVA? yes/no	14 Notes
1 No.	2 Title		4. Role	5 Scientific or Technical Field	6 Hrs/Run/Skill	7. Hrs/Day/Skill	8 * Tot Hrs/Mission/Skill	9 E or I†	10 Tasks	11. Duration (hr)	12 Freq		
XAP100	Launch Subsatellite	Launch	Technician	Electromechanical	2	2	2	N/A				Yes	
			Technician	Physics, Plasma	2	2	2	N/A					
			Experimenter	Physics, Plasma	2	2	2	N/A					
XAP110	Support Electron Accelerator	See AP-09-S											
XAP130	Support Shuttle EMI	Control and Position Subsatellite	Technician	Electromechanical	2	2	14	N/A				No	
		Control Instruments	Technician	Physics, Plasma	6	7	49	N/A				No	
		Monitor Data	Experimenter	Physics, Plasma	6	7	49	N/A				No	

PREPARATION INSTRUCTIONS:
* Based on mission duration (N) = 7 days.
† E = EVA, I = IVA

15. Total skill hours per day (Σ Col. 7) = 22 hr
16. Total skill hours per mission (Σ Col. 8) = 118 hr
17. No. of planned EVAs per mission = 0
18. Average duration per EVA = 0 hr

SORTIE PAYLOAD

PAYLOAD MISSION CONSUMABLES (ON-BOARD)

DATA SHEET NO. S-17 PAYLOAD NO. [illegible]
DATE 3-31-75 REV DATE [illegible] LTR [illegible]

PAYLOAD NAME DIAGNOSTIC PAYLOAD

EXPERIMENT		3 TYPE OF CONSUMABLE	USE RATE			STORAGE REQUIREMENT				11 Portion of initially stored consumables not returned to Earth (kg)	12 Notes
1 No.	2 Title		4 Wt. per Operation (kg)	5 Wt. per Day (kg)	6 Wt. per N Day Mission (kg)	7 Method, e.g., compressed gas cylinders, storage lockers, liquid vessel, self contained (in exp. equip.) etc.	8 Provided by E or S†	9 Weight at Launch (kg)	10 Weight at Landing (kg)		
AP 700	Maneuverable Subsatellite	Propellant	TBD	TBD	168	Self Contained	E	168	0	168	

PREPARATION INSTRUCTIONS
†Code E = Provided by experiment equipment.
S = Provided by Spacelab

13 Total weight of consumables at Launch (Σ Col. 9) = 168 kg.
14 Total weight of consumables not returned to Earth (Σ Col. 11) = 168 kg.

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SORTIE PAYLOAD
DATA ACQUISITION AND MANAGEMENT

1-200

DATA SHEET NO. S-19 PAYLOAD NO. A2-11-S
DATE 3-31-75 REV DATE ______ LTR ______

PAYLOAD NAME DIAGNOSTIC PAYLOAD

Req'ment Param / Mission Phase	SCIENCE [HOUSEKEEPING] DATA ACQUISITION* 1 Output Form - D,A,TV, Film, Voice, etc.)	2 Output Rate (bps, Hz, fps, Time, etc.)	3 No. of Channels or Film Size	Operations 4 Duration per Run or Obs. (hr)	Repetition Rate 5 Operations per Orbit	Repetition Rate 6 Operations per Day	7 Daily Total Data Quantity, D (bits) A (time & b.w.) TV, Voice (Time) Film (Frames)	CONTROL & DISPLAY 8 Personnel Stations	9 Image Displays	Experiment Controls 10 Type & Qty	Experiment Controls 11 Rate, (Opers per Hour)	Experiment Monitors 12 Type & Qty	Experiment Monitors 13 Rate, (Opers per Hour)	COMPUTER SUPPORT 14 Functions, e.g., Data Formatting, Stored Commands, Data Processing, G&N Computations, Pointing Control, etc.	Memory Size (Words) 15 Rapid Access	Memory Size (Words) 16 Bulk	17 Word Length (bits)	18 Opers per Sec.
Launch Pad/ Liftoff	N/A																	
Ascent	N/A																	
On-Orbit Operations	A	20 MHz	6	24	—	1	120 MHz Continuous (1)			TBD								
	D	3E05 bps Maximum	TBD	24	—	1	6E09 bits											
	[D	1000 bps	TBD	24	—	1	8.6E07 bits]											
Descent	N/A																	
Landing/ Post Landing (While in Orbiter)	N/A																	

ADDITIONAL ON-ORBIT OPERATIONAL REQUIREMENTS

19 Timing Accuracy Required, m sec TBD

Orbit Determination Accuracy Required

20 Position, km TBD

21 Velocity, m/sec TBD

22 Attitude Determination Accuracy Required, deg 0.25

23 Notes

(1) To be processed by a spectrum analyzer which is contained within the diagnostic control unit.

SSPD (S-19) 3-15-74

*Make separate entries for science and housekeeping data; include housekeeping data in brackets.

DATA SHEET NO. S-19